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FURROW IRRIGATION INTAKE WITH MULTIPLE TRAFFIC AND INCREASED AXLE MASS

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Summary:

Furrow irrigation infiltration on a slowly permeable clay loam was reduced by 23 and 33%, respectively, after one and two passes with a light 4.1 Mg (9,000 lb) tractor, and by 38 and 43%, respectively, after one and two passes with a heavy 8.2 Mg (18,000 lb) tractor; compared with 212 mm (8.3 in) infiltration for the check during a 8 h infiltration test after primary tillage. In a second test about 60 days after surface consolidation from the first irrigation, all furrow traffic treatments infiltrated about 20% less.

Keywords:

Furrow Irrigation, Furrow Traffic, Compaction Infiltration

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FURROW IRRIGATION INTAKE WITH MULTIPLE TRAFFIC AND INCREASED AXLE MASS[1]

R. R. Allen and J. T. Musick[2]

ABSTRACT

Pullman clay loam and related soils, the predominate soil types in the Southern High Plains, are slowly to moderately permeable, and furrow wheel traffic further reduces furrow irrigation intake rates. Traffic effects were evaluated with treatments of one (1) and two (2) furrow passes with relatively light (L) and heavy (H) tractors of 4.1 and 8.2 Mg (9,000 and 18,000 lb) mass, having 75% of the mass on the rear axle. Treatments are designated 1-L, 2-L, 1-H, and 2-H. Both larger tractor mass and repeated traffic increased tillage zone compaction and reduced irrigation intake rates and total intake. Soil strength (cone penetrometer) from wheel traffic compaction was greatest at the 100 to 150-mm (4- to 6-in) depth for all treatments, which is near the bottom of the 150-mm (6-in) primary tillage zone. For the first 8-h infiltration test using a flowing furrow infiltrometer after tillage, the 1-L, 2-L, 1-H, and 2-H treatments reduced average intake by 23, 33, 38, and 43% respectively; compared with 212 mm of intake for the no-traffic check. Because of furrow surface layer consolidation after the first irrigation, intake for all treatments was about 20% less during the second tests about 60 days later when the check infiltrated 171 mm and traffic induced intake reductions were 16, 23, 28, and 36% respectively; for 1-L, 2-L, 1-H, and 2-H treatments. A better understanding of variable furrow traffic effects on irrigation intake enables producers to make management adjustments to improve water application efficiency by beneficially using traffic compaction to reduce excessive early season intake or limiting traffic where low intake is a concern later in a crop season.

INTRODUCTION

On the Central and Southern High Plains, about 50% of the irrigated area is managed with graded furrow application, which is the predominate method on slowly permeable clay soils. Differential furrow water advance rates between wheel traffic and non traffic furrows has been observed by irrigators since the beginning of bed (ridge)-furrow irrigation culture. Irrigation water in traffic furrows advances more rapidly than in non traffic furrows which reduces water intake and increases tailwater runoff.

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Some producers may regard the differential advance as a management nuisance when traffic furrow stream sizes are reduced to obtain uniform advance of both traffic and non-traffic furrows and avoid excessive runoff. Others may purposely use the smoothing and compacting action of furrow traffic in all furrows to speed advance and reduce excessive intake, especially during the first application after primary tillage and forming furrows when the furrow surface is in a loose, roughened condition. Under these conditions, water intake rates can be relatively high. Preplant irrigations of 150-250 mm (6-10 in) have been measured after winter tillage on the fine textured Pullman clay loam in the Amarillo, Texas area (Musick and Lamm, 1990) which is in the 2.5 mm/h (0.1 in/h) basic intake rate class. These relatively high irrigation amounts can occur even though the rooting zone soil water storage deficit may be less than 100 mm (4 in) (Allen and Schneider, 1992). Excess intake results in losses to soil profile drainage and reduced application efficiency.

The beneficial effects of planned traffic in all furrows, as a furrow irrigation management tool, have been reported for moderately permeable to slowly permeable clay loams in the Southern High Plains by Allen and Musick (1992); Allen and Schneider, (1992); Musick and Pringle, (1986); Musick et al., (1985); and Musick and Walker (1987). The reported furrow water intake reductions from traffic ranged from 20 to 35% with advance times being reduced by about one half.

Kemper et al., (1982) reported that wheel reduced intake rates on silt loam soils at 15 locations in the Twin Falls, Idaho area by 12 to 80%. In these cases, the wide range in intake effects from traffic were largely attributed to varying soil water contents at the time of compaction. On a similar silt loam soil near Kimberly Idaho, Trout and Kemper (1983) reported that advance time was only 1/3 and steady state intake rate was 1/2 that of non-traffic furrows when a tractor wheel packed the soil ahead of the furrow opener. Eisenhauer et al. (1982) reported that wheel traffic reduced furrow intake up to 20-25% during the first application after tillage in South Central Nebraska when both conventional and reduced tillage systems were tested. Yoder et al. (1989) evaluated infiltration and wetting patterns beneath adjacent wheel and non-wheel furrows on a very fine sandy loam in Western Colorado and reported more intake and slightly more lateral movement of irrigation water from non-compacted furrows.

Regardless of the width of the row crop equipment used, which mostly varies from 4 to 12 row widths, at least two furrows are compacted by tractor wheels and an additional two furrows may be compacted to a lesser degree from implement carrier gauge wheels during a single pass. After initial bed-furrow forming; preplant cultivation, herbicide application, and planting can result in 2 to 3 tractor passes before growing season irrigations are applied. Thus, there can be added compaction effects from multiple passes or from increased tractor mass or axle load with relatively heavy equipment.

Soane et al. (1981), working in the United Kingdom, reported that the second pass of a wheel usually produces less increase in compaction than the first pass. However, the response to multiple passes will depend on the initial soil density and strength distribution with depth. For loose soils, compaction effects are much greater during the first pass than subsequent passes. Whereas, on soils which have appreciable initial strength, the compaction effect from the first pass may differ very little from subsequent passes. They also reported that the zone of maximum compaction approaches the surface with repeated passes. However, Voorhees et al. (1978) did not find this to be true in a 5 yr study in the Northern Cornbelt, possibly because of winter freezing action which decreased compaction in the 0-150 mm depth. In another study, Voorhees (1979) measured bulk density to the 300 mm (12 in) depth after multiple passes with a 7.3 Mg (16,000 lb) mass tractor. After one pass, increase in compaction was greatest in the 0-75 mm (0-3 in) depth, but after three passes the compaction increased with depth and was greatest from the 150-300 mm (6-12 in) depth.

In this experiment, we addressed the degree and depth of compaction caused by increased tractor mass and by successive traffic passes, and the resulting effects on furrow irrigation water intake.

PROCEDURE

The study was conducted in 1991 and 1993 at Bushland, Texas on 100 m (325 ft) length furrows, spaced 1.0 m (40 in) apart with no slope so that water intake would be relatively uniform along the furrow length. Plots were 10 m (33 ft) wide and were arranged in a randomized block design with 4 replications. The soil, a fine textured and slowly permeable Pullman clay loam (Torrertic Paleustoll), was described by Unger and Pringle (1981). This soil has a Ap horizon to about the 150 mm (6 in) depth, which is also the depth penetrated by most tillage operations. A relatively dense clay Bt horizon extends from 150-750 mm (6-30 in) in depth, having bulk densities of 1.5-1.6 Mg/m^3. The clay fraction is dominated by montmorillonite and the soil profile, when dry, develops shrinkage cracks that result in a relatively high initial water intake rate. After filling of cracks or saturation of a loosened surface layer, intake rates quickly decline to a low rate after 2 to 3 h and reach a basic rate after 8 to 12 h.

Soil preparation was accomplished by disking and chiseling 0.15 m (6 in) deep to incorporate residue from the previous crop. Furrows and beds were formed with 4-row equipment and furrow traffic treatments were immediately applied. On the non-traffic check; tractor wheel paths were under the beds during furrowing. Two tractors were used; a Deere 3020 with 4.1 Mg (9,000 lb) mass and a Case 2290 with a rear mounted tool carrier totalling 8.2 Mg (18,000 lb) mass. These tractors are designated light (L) and heavy (H), respectively, and span the mass range of many row crop tractors for 4 to 12 row equipment. The tractors were ballasted so that about 75% of the total mass was on the rear axle, which is common practice for 2-wheel drive tractors (Woerman and Bashford, 1983). Rear tire inflation pressures were 83 kPa (12 psi) and 166 kPa (24 psi), respectively, for the L and H weighted tractors.

Furrow treatments are listed as follows:

Check = No furrow traffic
L-1 = Light tractor, 1 pass
L-2 = Light tractor, 2 passes
H-1 = Heavy tractor, 1 pass
H-2 = Heavy tractor, 2 passes

After furrow traffic treatments were applied, gravimetric soil water contents were obtained by 0.3 m (12 in) core increments to the 1.8 m (6 ft) depth. Soil cone index measurements were made in furrows with a tractor mounted, hydraulic powered, cone penetrometer to the 0.6 m (24 in) depth for an indication of soil strength. The cone penetrometer, designed and constructed by G. L. Barker, is similar to a unit described by Williford et al. (1972). The penetrometer tip diameter was [20.27 mm (0.798 in), and the shape and rate of tip travel conformed to ASAE Standard 5313.2 for soil cone penetrometers (ASAE, 1989). Soil bulk density measurements were made in 50 mm (2 in) increments to the 300 mm (12 in) depth with a Troxler 3400[3] series nuclear density gage.

Infiltration measurements were made in 4.6 m (15 ft) blocked furrow sections with a flowing furrow infiltrometer, similar to that reported by Dedrick et al. (1985), before the first irrigation (preplant) in May of each yr and just before the second irrigation when grain sorghum was at about the boot stage of growth in July or early August. Grain sorghum was grown to deplete soil water content before the second infiltrometer measurement. Evaluation of soil compaction effects on grain yield were not included in the scope of this study.

RESULTS AND DISCUSSION

Soil Strength and Bulk Density

Measurements of soil strength (penetrometer cone index) with depth, immediately after wheel traffic compaction operations, are presented in Fig. 1. Voorhees et al. (1978) reported penetrometer resistance to be more sensitive to differences in compaction than bulk density.

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[3]The mention of trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by USDA-Agricultural Research Service.

For example, Voorhees found that wheel traffic only increased bulk density up to 20%, and differences were not significant below the 150 mm (6 in) depth. In contrast, the corresponding increases in cone resistance caused by traffic were up to 400%.

In this study, bulk densities at the 100-150 mm (4-6 in) depth, which correspond to the depth of peak soil strength (Figure 1), were similarly increased from 18 to 25% by the by the most severe (2-H) traffic treatment (table 1). Bulk density values under traffic furrows were higher in 1993 than in 1991 because of the higher soil water content and resulting compaction at the time of trafficking. Bulk densities for the 1-H treatments were 10 to 15% higher than for the 1-L treatments and the second pass of the heavy tractor only increased density slightly. The 2-L treatments did not produce a bulk density as high as the 1-H treatment. Unger and Pringle (1981) report bulk densities for undisturbed Pullman clay loam beneath the normal tillage zone in the Bt horizon from (6-16 inches) in depth to average 1.48 Mg/m^3. In this soil, most of the compaction from traffic (bulk density increase) occurs within the tillage depth zone and bulk densities of the naturally dense Bt horizon are affected very little.

In both years of this study, soil strength (Figure 1) under traffic furrows peaked at the 100-150 mm (4-6 in) depth which is the bottom of the Ap top soil horizon. The cone index values were less in 1993 because of higher soil water content [65% field capacity (FC)] at the time of measurement compared with drier soil (30-40% FC) at the time of trafficking in 1991. This emphasizes that soil strength, measured by penetrometer, is a function of soil water content as well as soil bulk density, which must be considered when making comparisons of different dates. In 1991, cone index values for the check increased markedly at the 75-125 mm (3-5 in) depth when primary tillage had been rather shallow. In contrast, primary tillage in 1993 was 150 mm (6 in) in depth which is reflected by lower cone index values in the tillage zone.

Infiltration Tests

Intake rate and cumulative intake depth curves, obtained from infiltrometer data, are presented in Figure 2 through Figure 5. The intake rate curves indicate traffic treatment effect differences during the first 3 h of a test, whereas the cumulative intake curves reflect increasing amounts with time and show traffic effects more clearly, especially near the end of tests. Total cumulative intake amounts for all treatments are presented in Table 2 for individual years, including 2-yr averages.

Intake Rates: For 1991, intake rates obtained shortly after furrow forming and trafficking (I-1) and those obtained after furrow consolidation from the first irrigation application (I-2) were similar in both tests, except that rates for I-2 dropped more rapidly during the first 30 min (Figure 2). This was the result of furrow consolidation after the first irrigation. In 1993, the intake rate curve for the I-1 check treatment (Figure 4) was similar to that in 1991 (Figure 2). However, the 1993 I-1 trafficked treatments had lower comparable intake rates during the first 3-h because of the greater compaction effect from relatively moist soil during trafficking. The very large drop in intake rates for test I-2 resulted from both furrow consolidation and relatively moist soil (50-60% field capacity) during the test on July 28 in 1993 as compared with test I-1 before furrow surface consolidation (Figure 4).

Cumulative Intake: The average effects of higher mass tractor load and repeated traffic on cumulative intake during tests are evident in table 2. Average intake reductions from traffic ranged from 23% for the 1-L treatment to 43% for two passes with the high mass (2-H) tractor during the first (I-1) test after primary tillage. Average intake for each treatment was about 20% less during the second (I-2) tests because of surface consolidation. Total intake amounts for the check treatments were nearly equal for the I-1 tests in both years, however intake reductions from traffic were larger in 1993 because of wetter soil (65% FC) during trafficking and a greater compaction effect on intake, which is apparent in Figures 3 and 5 and table 2. Even the light tractor caused considerable compaction on wet soil and a resulting 27% and 39% reduction in intake for one and two passes, respectively. Intake amounts for all treatments during the I-2 tests in 1993 are lower than in 1991, because of relatively moist soil (50 to 60% FC) during these tests also.

These results provide furrow irrigators an idea of the range of traffic compaction effects on irrigation water intake with differing soil water content during compaction, different tractor mass, and multiple passes on fine textured soils. On these soils that are apt of have low to moderate basic intake rates of 2.5 to 7.5 mm/h (0.1 to 0.3 in/h), the implications are that traffic can be confined to as few furrows as possible such as, two furrows per pass, using relatively wide 8 to 12 row equipment, thereby reducing the compacted area in comparison with narrower 4 to 6 row equipment. In instances where intake rates are excessively high during the first irrigation after tillage, planned traffic in all furrows can be beneficially used to reduce the high intake as discussed in the introduction.

CONCLUSIONS

1. In this fine textured soil, most of the compaction occurs within the tillage zone (Ap horizon) and soil strength and bulk density of the naturally dense Bt subsoil horizon are affected very little. Soil strengths (cone penetrometer) from wheel traffic compaction peaked at the 100-150 mm (4-6 in) depth which is the bottom of the Ap soil horizon.

2. Soil strength measured by cone penetrometer was a more sensitive to variation in compaction than was bulk density.

3. Repeated passes and larger tractor mass had increasing compaction effects on reducing irrigation water intake, especially during the first application after primary tillage. The greatest intake reduction effect from compaction occurred during the first traffic pass.

4. Relatively moist soil (above 60% FC) during traffic especially increased compaction and decreased irrigation intake, even for a relatively light 4.1 Mg (9000 lb) tractor.

5. Traffic induced reductions in intake were about 20% less during the second infiltration tests because of furrow surface consolidation from the first test.

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Table 1. Soil bulk density values at the 100-150 mm (4-6 in) depth near the bottom of the Ap soil horizon immediately after furrow trafficking.

Treatment	3-25-91	4-2-93
	Mg/m^3	Mg/m^3
Check	1.15	1.12
1-L	1.20	1.21
2-L	1.27	1.33
1-H	1.32	1.39
2-H	1.36	1.40

Table 2. Total cumulative irrigation intake amounts during 8-h infiltrometer tests and percent intake reduction as affected by wheel traffic compaction treatments, Pullman clay loam, Bushland, TX.

	1991		1993		Average	
	Total		Total		Total	
Treat.	Intake mm	Reduction (%)	Intake mm	Reduction (%)	Intake mm	Reduction (%)
<u>Test I-1</u>						
Check	210*	0	215	0	212	0
1-L	170	20	156	27	163	23
2-L	158	25	128	39	143	33
1-H	141	33	122	43	131	38
2-H	129	40	113	47	121	43
<u>Test I-2</u>						
Check	187	0	156	0	171	0
1-L	155	17	132	15	143	16
2-L	138	26	126	19	132	23
1-H	130	30	116	25	123	28
2-H	120	36	100	36	110	36

* 25.4 mm = 1 inch.

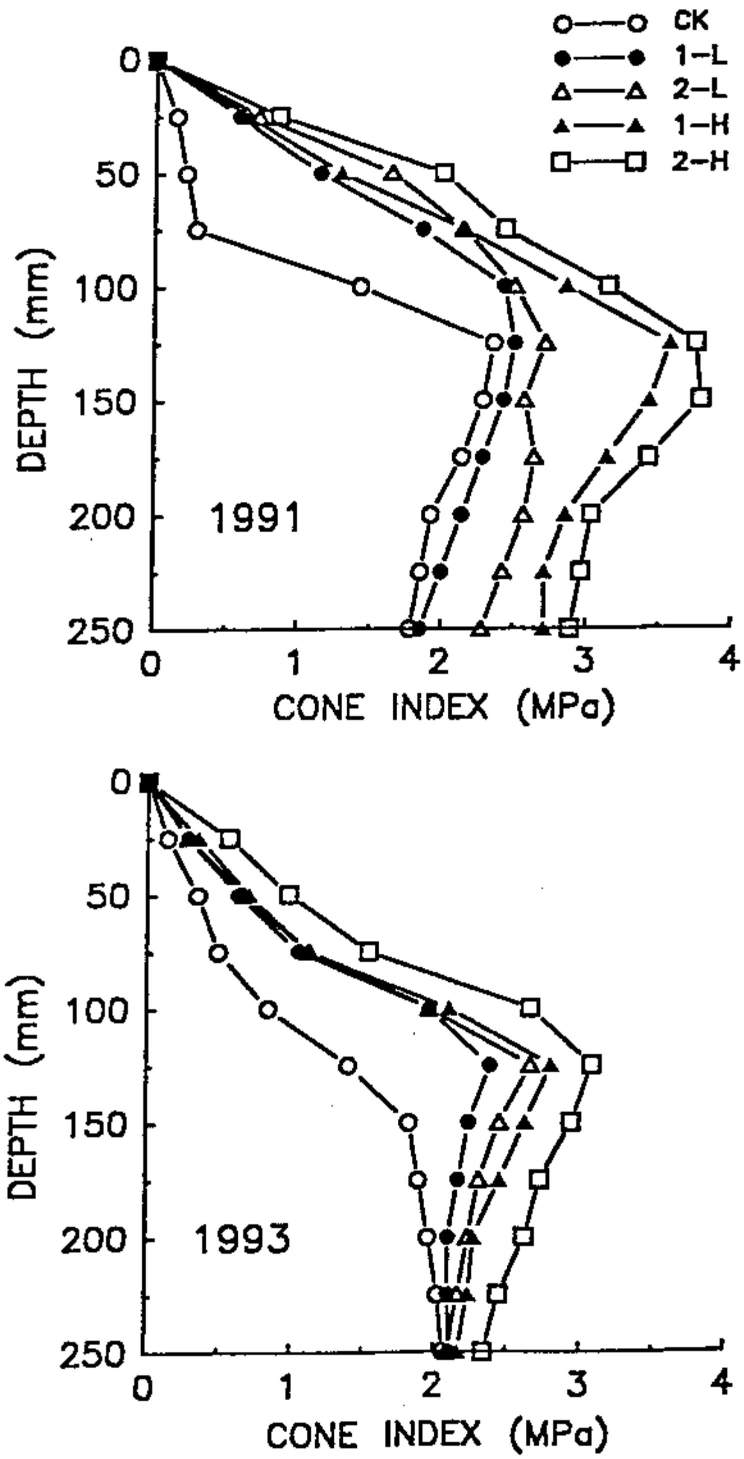


Figure 1. Cone index values of soil strength with depth obtained immediately after furrow traffic compaction. 25.4 mm = 1 in, 1 MPa = 145 psi.

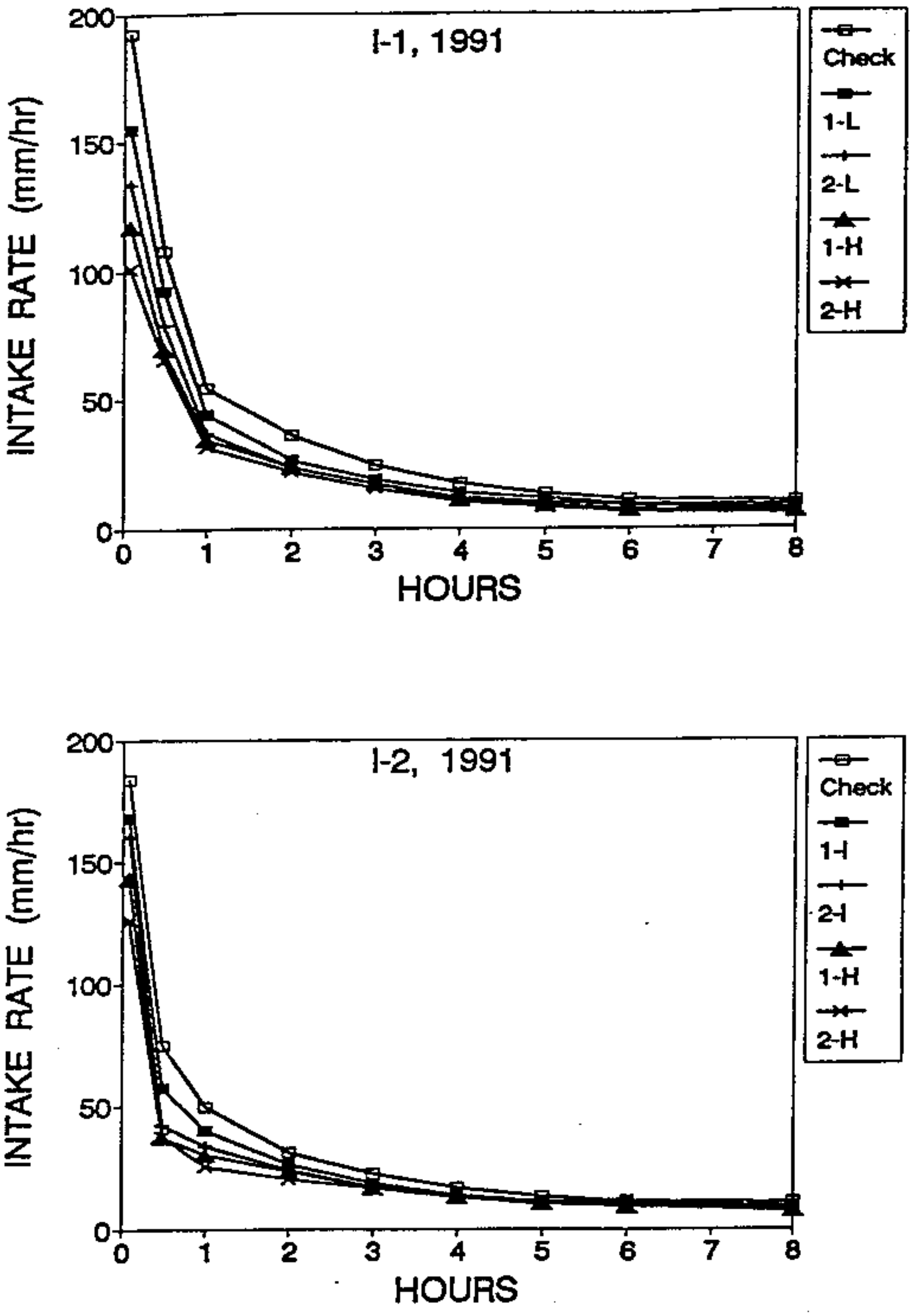


Figure 2. Irrigation water intake rate with time for the first (I-1) and second (I-2) applications in 1991. 25.4 mm = 1 in.

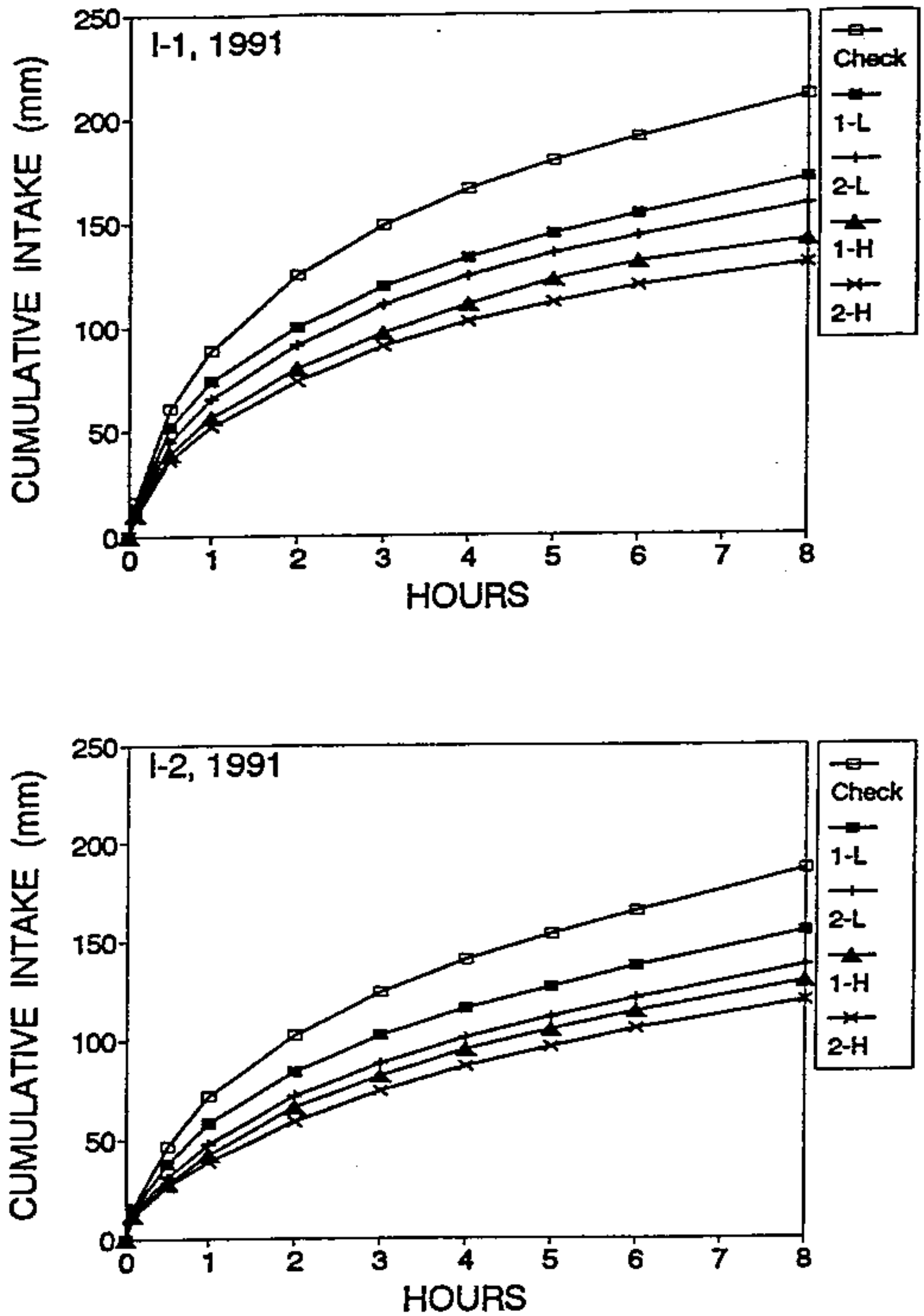


Figure 3. Cumulative irrigation water intake with time for the first (I-1) and second (I-2) applications in 1991. 25.4 mm = 1 in.

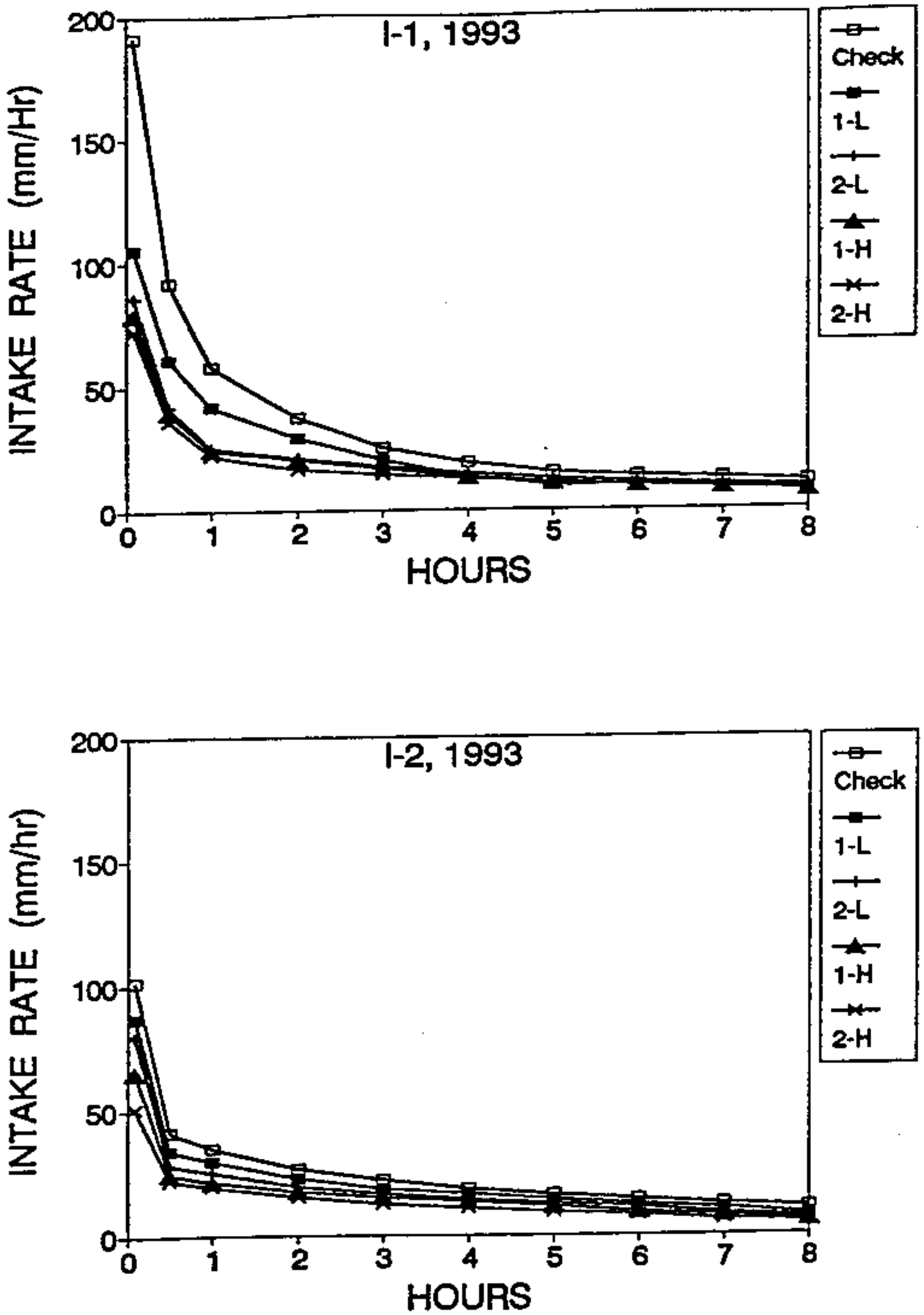
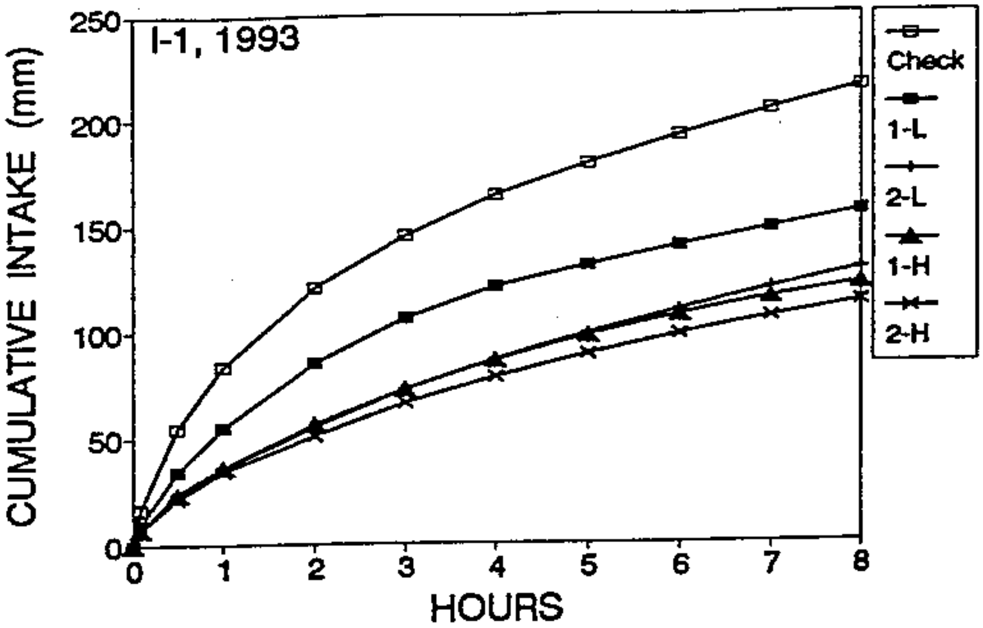


Figure 4. Irrigation water intake rate with time for the first (I-1) and second (I-2) applications in 1993. 25.4 mm = 1 in.



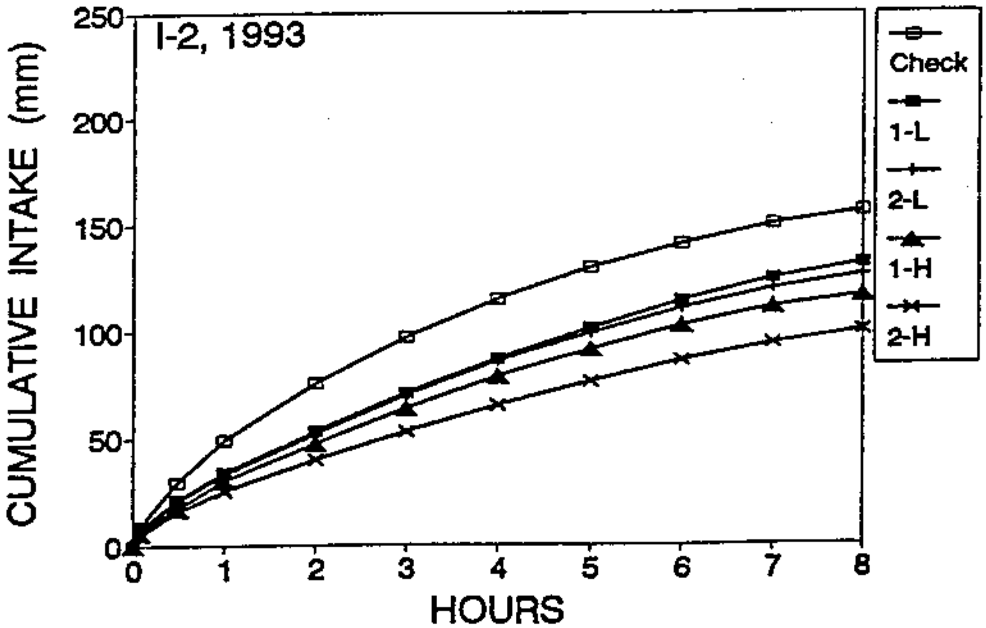


Figure 5. Cumulative irrigation water intake with time for the first (I-1) and second (I-2) applications in 1993. 25.4 mm = 1 in.